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यांत्रिक कपंन और प्रद्यात — मानव गतिविधि और कार्यकारिता में व्यवधान — वर्गीकरण

Indian Standard

MECHANICAL VIBRATION AND SHOCKS — DISTURBANCE TO HUMAN ACTIVITY AND PERFORMANCE — CLASSIFICATION

ICS 13.160

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

September 2001

Price Group 4

Mechanical Vibration and Shock Sectional Committee, ME 28

NATIONAL FOREWORD

This Indian Standard which is identical with ISO 9996 : 1996 ‘Mechanical vibration and shock — Disturbance to human activity and performance — Classification’ issued by the International Organization for Standardization (ISO) was adopted by Bureau of Indian Standards on the recommendations of the Mechanical Vibration and Shock Sectional Committee and approval of the Mechanical Engineering Division Council.

The text of ISO Standard has been approved as suitable for publication as Indian Standard without deviation. In the adopted standard certain conventions are not identical to those used in Indian Standards. Attention is especially drawn to the following:

a) Wherever the words 'International Standard' appear, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a full point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 2041 : 1990	IS 11717 : 2000 Vocabulary on — Vibration and shock (*first revision*)	Identical
ISO 5805 : 1997	IS 13281 : 1999 Mechanical vibration and shock affecting man — Vocabulary (*first revision*)	do

Indian Standard

MECHANICAL VIBRATION AND SHOCKS — DISTURBANCE TO HUMAN ACTIVITY AND PERFORMANCE — CLASSIFICATION

1 Scope

This International Standard lays down a simple classification of motion- and vibration-sensitive human activity and task performance. The classification includes, and is intentionally limited to, volitional human activity and task performance known or presumed to be disturbed, degraded or disrupted by continuous, intermittent, transient, or repetitive oscillatory motion or vibration (including shock motion) of human beings, components of their task, or their surroundings. This classification applies only to volitional human activities and tasks, interference with which by motion or vibration is presumed to be mediated by direct mechanical intrusion, physiological (non-injurious) changes in the person affected, or reversible sensory impairment, distortion, or conflict caused by the motion or vibration.

It does not extend to activity or performance reduction associated with disability due to motion- or vibration-related injury. This International Standard is intended specifically to be an aid in the formulation of standard guidelines for the evaluation of human whole-body exposure to mechanical vibration and shock in the frequency range 0,1 Hz to 80 Hz, when *optimization of human activity and task performance* in the mechanical environment is the main criterion of evaluation.

NOTE 1 This International Standard also provides definitions of specialized terms, not defined in other standard vibration and shock vocabularies, that find a particular use in human biodynamics relating to task performance. It therefore supplements the biodynamical vocabulary in ISO 5805.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2041:1990, *Vibration and shock — Vocabulary.*

ISO 5805:—[1], *Mechanical vibration and shock — Human exposure — Vocabulary.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 2041 and ISO 5805 and the following definitions apply.

3.1 human volitional activity:

Any consciously directed human action that is performed electively, i.e. for a purpose or in a manner that is not immediately essential to the performance of a specific task in hand, or that is not required of the person by virtue of his essential presence in a situation or function in a system as a human operator.

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[1] To be published. (Revision of ISO 5805:1981)

NOTE 2 Examples of human activity in this sense are: walking, eating, reading, writing or trying to sleep in a train, ship or other vehicle, and trying to sleep, rest, enjoy general amenities or carry out some fine task of choice in a building that may be shaken by internally or externally generated vibration or impact. The distinction from task performance may be rather fine in many operational contexts. For example, a seaman who, because of violent ship motion, has difficulty traversing a deck or climbing a ship's ladder to get to or from his quarters in heavy weather experiences interference with activity. Interference with task performance would begin when he is at his workstation, engaged in his assigned duty. However, a shipmate whose assigned task it was to traverse the same rolling deck while hauling on a rope or transporting ship's equipment or materials would be experiencing interference with task performance. (In either case, an occupational hazard may arise when the effects of the ship's motion on the seaman's locomotion and ability to concentrate on what he is doing become severe enough to undermine safety.)

3.2 task performance:

Any learned or skilled activity that is carried out of necessity or by direction as part of an assigned duty. In such a situation, the receiver of motion or vibration exposure is acting in his capacity as a human operator, monitor, inspector, crew member, supervisor or controller in a mechanical environment, where adverse effects of motion or vibration may prejudice efficiency, productivity, safety, or some other attribute of the work, process or mission.

NOTE 3 Examples of task performance in this sense include driving a vehicle, piloting an aircraft or navigating, standing watch or carrying out any assigned duty aboard ship, operating or monitoring an industrial plant, process or machine, or carrying out some specialized task (for example instrument assembly, quality inspection, microsurgery, fine craftsmanship such as making or repairing jewellery) in a building or other structure subject to disturbance by vibration or impact.

3.3 afferent:

Pertaining to nervous pathways or neural signals conveying information about the body or the external world from the peripheral receptors to the central nervous system and the brain.

3.4 arousal:

State or degree of activation and alertness of the central nervous system.

NOTE 4 Specific parts of the brain and central nervous system maintain and regulate this state, in response to both external and internal factors. According to prevailing theory, there is an optimal level of arousal for task performance. The optimum is not necessarily the maximum: both under- and over-arousal may diminish skilled performance [see 4.3.2.2 c)].

3.5 (human) operator:

Person engaged in task performance, considered as a monitoring, controlling or directing element in a system or process capable of a dynamic response to system inputs and disturbances.

NOTE 5 For many purposes in human factors engineering, sufficient data exist to enable the human operator to be considered (and modelled mathematically) as a quantifiable element or processor in a "man-machine" system (for example pilot and aircraft).

3.6 low-frequency motion:

Continuous or transient oscillatory motion of components of the vibration spectrum affecting human beings at frequencies below 1 Hz.

NOTE 6 The conventional frequency of 1 Hz separating low-frequency oscillatory motion from what is popularly known as "vibration" (although no such distinction exists in physics) is not entirely arbitrary and has some practical significance when dealing with human exposure to vibration. For instance, mechanical resonance phenomena in humans occur mainly at frequencies above 1 Hz, while motion sickness is provoked only be oscillatory motions at frequencies below about 1 Hz. As another practical matter, specialized inertial instrumentation and analytical techniques may be called for when recording and evaluating motion of very low frequency and large displacement amplitude. Moreover vibration isolation and conventional vibration control engineering techniques may not be readily applicable at very low frequencies.

3.7 motor (performance or activity):

Descriptive of the function or output of the musculoskeletal system of the body, by which man regulates his own posture and exerts physical action upon the external world, for example when using a tool, operating a computer keyboard, controlling a vehicle, or communicating with others by speech or gesture.

3.8 neuromuscular:

Pertaining to the muscles (specifically, in the context of human performance, the skeletal or "voluntary" muscles that subserve conscious, volitional action) and to the motor nerves and higher centres of the nervous system that control them.

3.9 oculomotor:

Pertaining to the voluntary and reflex movements of the eyeballs with respect to the skull, and to the generation and neuromuscular regulation of eye movements.

3.10 reference posture:

In biodynamics, a notional orientation and posture of the human body considered as a receiver of mechanical vibration and shock.

3.11 sensory:

Pertaining to the organs and physiological mechanisms by which the human brain acquires information ("input") about the world, enabling human beings to know, relate to, and influence the external world by volitional action. Sensory organs and neural mechanisms also subserve an internal function, which may be conscious or unconscious, namely, permitting the living body to monitor and respond to its own physiological state and to changes in that state arising from internal or external causes.

NOTE 7 Low-frequency motion and vibration are perceived by means of a variety of sensory organs and receptors. These include the eye, the vestibular (balance) organs of the inner ear, and a range of microscopic organs (mechanoreceptors) distributed in the tissues throughout the living body that variously signal changing pressure, tension, position, vibratory motion, etc. The organs of special sense, particularly of hearing and sight, also provide motion and vibration cues to the brain in many circumstances.

3.12 sensorimotor:

In the context of biodynamics, pertaining to the sensory input of information to, and the motor action (output) of, the human operator functioning in a dynamic environment.

3.13 sopite syndrome:

A state of sleepiness, lassitude, or drowsy inattention induced by motion or vibration.

3.14 vestibular:

Pertaining to the organs of balance (part of the labyrinth, whence the term, labyrinthine) in the inner ear, and to their functional connections with the brain and central nervous system.

3.15 volitional:

By the exercise or direction of the will. Used of human motor activity (including task performance), carried out as the result of exercise of the conscious will, i.e., not automatically or as an unconscious reflex action.

4 Classification

4.1 Categories of activity and task performance

The taxonomy is entered for either of the categories of learned or skilled human action, defined under 3.1 and 3.2, volitional activity or task performance.

4.2 Classes and varieties of action that may be affected by motion or vibration

4.2.1 Acquisition of information

4.2.1.1 Visual system

a) Visual stimulus (signal) detection

b) Visual motion detection

c) Visual resolution (acuity)

d) Other visual functions (for example colour discrimination)

4.2.1.2 Other sensory systems

a) Hearing

b) Vestibular system

   1) Sense of balance and orientation

   2) Low-frequency motion sense

c) Distributed mechanoreceptors

   1) Vibrotactile sense

   2) Sense of gravity and incident mass

   3) Sense of position of body members

   4) Sense of force/strength

4.2.2 Central processing of information (cognitive function)

4.2.2.1 Visual pattern recognition

4.2.2.2 Visual search

4.2.2.3 Spatial perception and orientation

4.2.2.4 Recognition and processing of speech and other auditory signals

4.2.2.5 Vigilance (visual and auditory) and concentration

4.2.2.6 Time perception and estimation

4.2.2.7 Mental computation

4.2.2.8 Reasoning

4.2.2.9 Other cognitive functions

4.2.3 External activity and task execution (motor function)

4.2.3.1 Static postural function

a) Stability of stance/whole-body (or head) orientation

b) Maintenance of fixed postures of limbs/extremities

4.2.3.2 Kinetic (moving) postural function

a) Locomotor skills (human locomotion, load-carrying and -handling, coarse manual and pedal control operations, including continuous tracking)

b) Fine manipulative skills (manual dexterity)

c) Speech

4.3 Mechanisms of impairment of disruption of human activity and task performance by low-frequency motion and vibration

4.3.1 Direct mechanical interference

4.3.1.1 Disruption or degradation of sensory input from task or activity

a) By vibratory displacement of head, eye or intraocular structures

NOTE 8 Such effects (for example blurring of vision) are associated particularly with resonance phenomena in major body structures up to 30 Hz. Accordingly, the effect is apt to be of immediate onset, markedly frequency-dependent, and closely correlated with the time-course of the mechanical stimulus.

b) By oscillatory relative displacement of visual surroundings or point of regard (indirect vibration) (for example vibration of pointers on scales, making them difficult to read)

4.3.1.2 Disruption or impairment of human motor output (i.e. the input to the activity or task)

EXAMPLES

a) By mechanical interference with the smooth course of locomotion or by oscillatory displacement of the human point of contact with the task (for example hand/control, foot/pedal, finger/keypad)

b) By dislodgement of objects of human activity or task performance (for example loose or mobile objects which it is intended to handle or pick up)

c) By instantaneously confusing subjective estimations of the position, weight or inertia of loads to be lifted or moved (for example aboard a rolling ship)

d) Vibratory distortion of articulation (speech)

4.3.2 Indirect or central (physiologically mediated) effects

NOTE 9 Physiologically mediated effects of motion and vibration may persist for variable periods (minutes to days) after the provocative mechanical disturbance has ceased.

4.3.2.1 Impairment of sensory input and perception

a) By disturbance of visual function

    1) By motion-induced destabilization of oculomotor control (for example nystagmus)

    2) By changes in visual function (for example colour or contrast sensitivity) at the receptor level

b) By impairment of auditory function

    1) By auditory masking of speech or other auditory signals by lower-frequency vibration-induced noise

    2) By temporary elevation of the threshold of hearing (temporary threshold shift)

c) By masking or impairment of the vibrotactile sense

    1) By threshold elevation, distortion or masking of afferent signals from vibrotactile receptors

    2) By sensory fatigue at the receptor level

d) By impairment or disturbance of vestibular function (leading to postural instability or to disorientation)

e) By impairment, disturbance or pre-emption of the function of deep (muscle, tendon and joint) mechanoreceptors and associated neural (including reflex) pathways subserving postural activity

f) By enhancing sensory impairments associated with other stressors simultaneously present in the combined motion or vibration environment (for example noise, heat, glare)

4.3.2.2 Impairment of cognitive function (central processing of information by the brain) and attention

a) Disorders due to perceptual conflict and distraction

   1) Perceptual distraction by vibration and noise

   2) Motion-induced perceptual conflict disorders:

      i) Spatial disorientation

      ii) Motion sickness

NOTE 10 Motion sickness (popularly named airsickness, seasickness and so on, according to context) is a commonly experienced and sometimes severe but reversible (i.e. physiological) disorder specifically associated with exposure to actual or perceived oscillatory motion in the frequency range 0,1 Hz to 1 Hz. One or more of a constellation of symptoms (with or without frank vomiting) may afflict the sufferer. In severe cases it is immediately and profoundly disruptive of motivation, concentration, activity and task performance in both individuals and groups, but in the less severe case with premonitory manifestations it remains an open question whether individual task performance is degraded until activities are interrupted or abandoned. Group performance (for example the work of a ship's department) may be delayed or impaired by attrition in the crew. The malady afflicts sufferers in a highly idiosyncratic manner. Most sufferers can benefit from diminishing effect of continued or repeated exposure to the provocative stimulus (habituation).

b) Sopite syndrome

c) Alteration of the level of arousal

NOTE 11 According to a current, widely-held theory, the human operator performs best (particularly at essentially "mental" tasks, such as vigilance) at an optimal (not necessarily maximal) level of arousal for the task in hand and the individual's physiological state. The state of arousal or "alertness", of the organism is maintained and regulated by the ascending reticular activating system of the brainstem: it is a function crucial to the wakeful activity of the forebrain. Excessive arousal, however, may lead to erratic and error-prone performance in certain kinds of task. Profound lowering of arousal, on the other hand, may also result in decreased performance, (for example increased errors of omission in vigilance tasks), in this case due to lassitude, drowsy inattention or actual sleeping on the job. Profound lassitude and drowsiness have been specifically identified as the sopite syndrome when associated with low-frequency (below 1 Hz) motion such as is commonly experienced aboard ships. The neurological basis of the sopite syndrome, and its relationship to classical sickness, remain open questions in physiological science.

d) Effects of fatigue

   1) Sporadic interruption or blocking of thought, resulting in mental processing delays or errors in computation or reasoning

   2) Inattention and errors of omission

   3) Loss of motivation and increase in apathy or tendency to withdraw from the task in hand

   4) Loss of clarity or precision in speech and perception (affecting reliability of verbal communication)

NOTE 12 The term "fatigue" as used here is a human condition that has defied exact definition by physiologists, psychologists and human engineering specialists since scientific attempts to define it began in the early year of this century. As a subjective entity affecting motivation to perform a task or continue volitional activity, it encompasses both "mental" fatigue (tiredness, desire to abandon activity for sleep or rest) and the feeling of physical exhaustion (which can be experienced while wide awake and without feelings of tiredness). Objectively, fatigue has been defined as that combination of time-related physiological (i.e. reversible) impairments which degrades human performance.

4.3.2.3 Degradation of task execution (motor output)

a) Intention tremor, postural instability, loss of smoothness of gait, manual or other motor (muscular) effort, "overshooting", and other manifest signs of impaired neuromuscular control

b) Loss of clarity, precision and power in speech generation (affecting reliability of verbal communication)

c) Impairment or loss of transfer of acquisition (learning) of motor skills

NOTE 13 As a general rule, the direct mechanical effects of low-frequency motion or vibration upon human activity and performance are strongly force (acceleration) and frequency dependent, and not strongly dependent upon exposure time. That is because of the mechanical (i.e. not physiologically mediated) nature of such effects, and the fact that they are generally related to the dynamic characteristics of the body behaving as a lumped parameter damped mass-spring system (at least for frequencies below about 50 Hz). Hence, the direct mechanical effects (for example blurring of vision) typically begin immediately with the onset of the disturbing motion or vibration, persist fairly constantly with continuation of the motion, very monotonically with changes in vibration intensity, and cease when the mechanical disturbance ceases. On the other hand, the "central" or physiologically mediated effects of oscillatory motion on performance are often not clearly related to vibration frequency, being more dependent upon a composite function of exposure time and severity of exposure.

4.4 Duration of impairment

With the notable exception of motion sickness (a response limited to provocative motions in the decade 0,1 Hz to 1 Hz), impairments of cognitive activity and "central" task performance can potentially occur at high enough intensity over a broad range (at least 10 octaves) of vibration frequency. Moreover, such effects (for example impairment of vigilance or thinking) do not usually manifest themselves (and indeed are difficult to evaluate) until the motion which is of high enough magnitude and performance of the task in it have been going on for some time (hours), and, once manifest, impairment is apt to worsen with the passage of time, unless some habituation or accommodation to the motion takes place, or some alerting, uplifting or alleviating event or factor intrudes upon performance of the task. Furthermore, certain physiological effects of oscillatory motion (for example, fatigue, postural instability, motion sickness and consequent loss of motivation) do not disappear abruptly with cessation of the provocative motion but are apt to persist for some time (minutes to hours, even days in severe cases) after it has stopped. For this reason, an affected person's performance may remain impaired even after a ship has docked or an aircraft has landed following a rough passage.

Annex A

(informative)

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[5] Griffin, M. J. *Handbook of Human Vibration.* Academic Press, London and New York, 1990.

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2) To be published. (Revision of ISO 2631-1:1985)

3) To be published.

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This Indian Standard has been developed from Doc : No. MED 28 (558).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Prabhat Offset Press, New Delhi-2